acid varies greatly with each situation. It can range from such simple equipment as a safe, spill-proof container used to pour acid directly into a water reservoir—all the way to sophisticated flow measuring and injecting equipment.

At this point in your planning it is highly beneficial to have employed the services of a licensed professional engineer to assist in the design work and the selection of proper equipment to fit your particular needs.

CONCLUSIONS

It is not only possible but also practical and cost-effective to treat high-bicarbonate water to improve its quality. This undertaking, however, requires a careful plan to maintain proper safety as well as considerable knowledge of types and sizes of injection equipment available. For these reasons, I think it is ill-advised to proceed with a treatment plan without consulting a professional engineer who is familiar with this type of work.

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CALCIUM, MAGNESIUM, AND IRRIGATION WATER

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For years great emphasis has been placed on "proper pH" of container growing media, and dolomite (calcium and magnesium carbonate) has been used almost exclusively to raise the pH to the chosen level (1, 2). As nutrition in containers becomes more precise, calcium and magnesium nutrition must be modified. Many irrigation waters contain substantial quantities of dissolved calcium and magnesium. Whitcomb (4,5) studied this extensively in Oklahoma and found that with a water that contained 40 ppm calcium and 17 ppm magnesium, two pounds of dolomite was optimum for greenhouse and container nursery crops. Alternative sources of calcium and magnesium also exist. These may be especially useful in areas where the water supply contains considerable calcium but little magnesium, or vice versa.

In order to study the combinations of water quality, calcium, and magnesium nutrition, and various sources of both elements a study was conducted in two locations during 1987. Analysis of the irrigation water at the two locations was as follows, in parts per million:

	Na	Ca	Mg	HCO_3	B	Cl	SO_4	Total* salts	pH
Bennetts Creek Nsy. Suffolk, Va.	30	20	9	100	0.13	48	28	0.36	8.3
Jon's Nursery Eustis, FL.	10	60	19	88	0.01	12	174	0.39	7.3

*mmhos/cm

Treatments were:

1) no calcium or magnesium.
2) calcium only, using calcium carbonate, added at a rate equivalent to 6 pounds of dolomite per cubic yard.
3) three levels of 100 mesh dolomite.
4) olivine, which contains 14 percent magnesium as a ferrous magnesium silicate, at three levels.
5) magnesium oxide (58% Mg) at three rates.
6) fine particles of MgO, coated with molten sulfur.
7) coarse particles of MgO, coated with molten sulfur.

For all rates of olivine, calcium carbonate was used to provide a 2:1 Ca:Mg ratio. This procedure was also used for the three sources of magnesium oxide. See Table 1 for specific rates and plant response. Note that because the chemicals were weighed out in advance and the container sizes at the two locations varied (150 cubic inches in Florida and 210 cubic inches in Virginia) the rates in pounds per cubic yard also varied between locations.

Olivine has been reported as beneficial for field-grown nursery stock as a magnesium source and has a solubility roughly the same as dolomite (3). Magnesium oxide is extremely insoluble in water (0.00062 g/100 ml) and, in general, has not been effective as a magnesium source for container nursery stock. The idea of coating granules of MgO with sulfur was tried in hopes of increasing the solubility of the MgO as a result of a reaction with the sulfuric acid formed upon the degradation of the sulfur.

Container growth medium in Florida was 60 percent ground pine bark, 20 percent peat, and 20 percent sand. In Virginia 80 percent ground pine bark and composted hardwood bark and 20 percent sand was used. All treatments received 1.5 pounds of Micromax per cubic yard as the micronutrient source and 18-6-12 Osmocote at the rate of 11.5 lbs/yd^3. Test species were (azalea) *Rhododendron* 'Southern Charm', (juniper) *Juniperus conferta*, 'Blue Pacific', and (holly) *Ilex cornuta* 'Dwarf Burford' in Florida; (azalea) *Rhododendron* 'Hino-crimson', (holly) *Ilex vomitoria*, 'Shillings Dwarf', and (juniper) *Juniperus horizontalis* 'Wiltonii' (also called 'Blue Rug') in Virginia. The duration of the study was from April 17 to November 22 in Florida and May 2 to November 17 in Virginia. The plants were given a visual grade from 1 to 10 where 1 = a poor plant and 10 = an excellent plant, using a selected set of standards for a grade of 1-4-7 and 10. Top weights were also determined.

The studies were conducted in both locations in full sun and with standard practices of watering, pruning, weed control, etc. for that nursery. Each treatment was replicated six times with each species in each location. Treatments were arranged in a randomized block design. Border rows of containers filled with mix but no plants were placed on the east, south, and west sides of each block to avoid adverse temperature effects.

To ensure that each container received a precise level of all nutrients, all chemicals were weighed out prior to the study and placed in small zip-lock bags. The procedure used in mixing was as follows:

a) the nurseryman prepared the mix with no chemicals added,
b) the containers were filled and watered,
c) the mix in a container was emptied into a plastic pail,
d) the contents of the zip-lock bag were added,
e) the mix and nutrients were mixed by hand, then returned to the container. This procedure prevents any error in quantities of chemicals received in a container due to mixing.

RESULTS AND DISCUSSION

In Florida, azalea, holly, and juniper all grew best when no calcium and magnesium were added to the components of the growth medium (Table 1). The azaleas averaged a visual grade of 9.7 and 136 grams of top weight. The next best treatment was 1.2 lb. per cu. yd. of sulfur-coated fine MgO with a visual grade of 7.7 and 119 grams top weight. The current grower practice was approximately eight lb. of dolomite per cu. yd.

The holly in Florida averaged 8.2 visual grade and 118 grams top weight with no Ca or Mg. Olivine at 3.5 and 7.0 pounds, dolomite at 3.5 and 7.0 lb. and fine MgO with a sulfur coat at 2.5 lb. per cu. yd., all had similar top weights but visual grades were somewhat lower.

Table 1. Summary of calcium and magnesium study, Virginia and Florida, 1987[1].

	Virginia							Florida					
	azalea		holly		juniper			azalea		holly		juniper	
Va. rate[2]	Visual grade[2]	Top wt.	Visual grade	Top wt.	Visual grade	Top wt.	Fla. rate	Visual grade	Top wt.	Visual grade	Top wt.	Visual grade	Top wt.
0	9.0	105	5.6	25	5.8	92	0	9.7	136	8.2	118	8.0	135*
Ca only	8.5	85	7.2	25	6.3	104	Ca only	7.3	113	6.8	107	6.3	124
Dol.[4], lb./yd.^{3}													
2.5	8.7	106	7.3	25	6.5	107	3.5	5.5	108	6.8	122	5.8	120
5.0	8.2	97	7.0	24	6.7	103	7.0	6.8	119	6.8	117	5.7	125
7.5	7.0	81	6.2	17	7.2	104	10.5	5.8	100	7.0	116	5.0	112
Olivine[4], lb./yd.^{3}													
2.5	7.0	83	5.5	18	8.0	110	3.5	7.2	112	5.7	116	5.3	121
5.0	8.2	89	6.5	20	7.3	104	7.0	7.0	93	7.3	120	6.5	129
7.5	8.5	88	6.7	20	5.8	100	10.5	6.5	102	6.0	94	4.0	108
Fine MgO[4],lb./yd.^{3}													
0.8	7.0	74	6.8	21	7.7	102	1.2	5.8	90	5.0	110	4.3	103
1.6	7.0	72	6.8	22	7.8	99	2.4	4.7	87	5.8	105	4.8	104
2.4	5.7	60	6.2	19	6.7	98	3.6	4.5	78	3.7	87	5.2	115
Fine MgO + S, lb./yd.^{3}													
1.3	9.0	103	6.3	23	6.3	98	1.7	7.7	119	5.8	84	6.5	121
2.5	9.0	103	7.2	25	5.8	97	3.5	7.5	108	6.3	120	3.8	101
3.7	8.3	99	6.8	25	5.8	91	5.3	6.0	94	4.2	89	3.5	83
Coarse MgO + S, lb./yd.^{3}													
1.2	8.2	91	7.0	22	6.7	100	1.7	7.0	120	6.5	105	6.2	125
2.5	8.7	99	7.3	23	6.8	102	3.5	7.8	117	6.5	102	5.8	117
3.7	8.7	96	6.0	21	6.3	94	5.3	6.5	95	4.8	97	5.3	104

[1] Top weight and visual grade on November 19, (Florida) and November 16 (Virginia).
[2] Rates in Florida and Virginia differed due to container sizes.
[3] Visual grade based on 1 to 10, where 10 was best
[4] *Olivine was 32% iron and 14% magnesium.* MgO was magnesium oxide, which contains 58% Mg. Fine MgO + S and coarse MgO + S were magnesium oxide granules coated with molten sulfur, then reground to expose some of the MgO granule. Dolomite was 180-mesh, face-powder consistency. Olivine and MgO treatments had calcium carbonate added to make a 2:1 Ca:Mg ratio.
*Best treatment overall.

The juniper in Florida averaged 8.0 visual grade and 135 grams top weight with no Ca or Mg. Plants receiving olivine at 7.0 lb. , dolomite at 7.0 lb. and 1.2 lb. of sulfur-coated coarse MgO all had top weights approaching the best treatment. However, visual grades were 6.5, 5.7, and 6.2, respectively, and plants were distinctly lower in visual quality.

In Virginia the best treatment was approximately 2.5 lb. of dolomite. However, the difference between 2.5 and 5 lb. was small for all three species. In addition, in Virginia there were several good treatments and a less well defined clear "winner". For example, visual grade was 9.0 and top weight 105 for azalea with no calcium or magnesium, vs. 8.7 and 106 with 2.5 pounds of dolomite. Likewise, plants receiving fine MgO + sulfur at 1.2 and 2.5 pounds per cubic yard had 9.0 and 103 visual grade and weight. However, for holly, only 2.5 pounds fine MgO + sulfur and 2.5 pounds coarse MgO + sulfur gave visual grade and top weights equal to the 2.5 pounds of dolomite. With juniper, 5.0 and 7.5 pounds of dolomite, 2.5 and 5.0 pounds of olivine, 0.8 pounds fine MgO + sulfur and 1.2 and 2.5 pounds coarse MgO + sulfur all had comparable visual grades and top weights.

The reason for the less well-defined results in Virginia may be due to the presence of some 10 to 20 percent composted hardwood bark in with the pine bark of the mix. Hardwood bark contains considerably more calcium than pine bark, which probably affected the plant response to the treatments and somewhat clouded the results.

It is interesting to note that the lowest pH of the mix at the end of the growing season in either location was 5.4, where no calcium or magnesium were added. The highest pH was 5.9 where 10.5 pounds of dolomite had been added to the mix in Florida. In both locations, pH change of the mix was buffered from change, but for different reasons. In Florida, the calcium, magnesium, and bicarbonates in the water prevented the pH of the mix from becoming extremely acid. In Virginia the buffer effect was provided by the hardwood bark portion of the mix and to a lesser extent by the calcium, magnesium, and bicarbonates.

The results of these studies support the hypothesis that it is the level of calcium and magnesium available to the plant that is important and not pH (4, 5). At the same time it should be noted that if the levels of these two elements are generally correct, the pH will also be in the "desirable" range.

In other locations, using other mix components and quality of irrigation water, olivine and/or magnesium oxide may be useful, although they provided no advantage in this study.

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